CHAPTER 2

ROADS

2-1. Application. Recreation roads are designed and built primarily to support and provide recreation experiences. A large percentage of recreation visitors are sightseers and roads are primary recreation facilities for them. National policy places emphasis on safety, aesthetics, and accessability to the physically handicapped in design of public facilities. Road designers must be sensitive to and routinely incorporate these features in Corps designs. Designers should be familiar with and follow the general road design standards set out in this manual. The road terminology used in this chapter is that of the American Association of State Highway and Transportation Officials, AASHTO (formerly AASHO). Design of a park road should be accomplished by an interdisciplinary team of professionals.

2-2. Controls.

a. Topography and Physical Features.

(1) General. Special knowledge and concern for protection of the resources and aesthetics of the area through which the access road passes and of the area where the recreation facilities are to be developed are essential tools of the recreation road designer. A complete knowledge of topography, physical features, and recreation facilities is required and the best location for each has to be determined prior to detailed design of the access and circulation road. Information regarding topography, land use and physical features, together with traffic data form the major design controls. The other design controls discussed below depend largely on these controls. Since topography and land use have such a pronounced effect on road geometrics, information regarding these features should be obtained in the early stages of planning and design. Photogrammetry at the proper scale and contour interval is most helpful.

(2) Types of Topography (Terrain). General topography types are established here for classifying terrain for common understanding in their application to design needs. Classification pertains to the general character of the specific route corridor. Classification is established here in terms of difficulty the design vehicle would encounter when a recreation road is placed on that terrain. Level terrain would not cause the design vehicle towing heavy loads to reduce to speeds below those of passenger cars on any section of the road. In general, rolling terrain causes vehicles towing heavy loads to reduce to speeds below those of passenger cars on some sections of road.

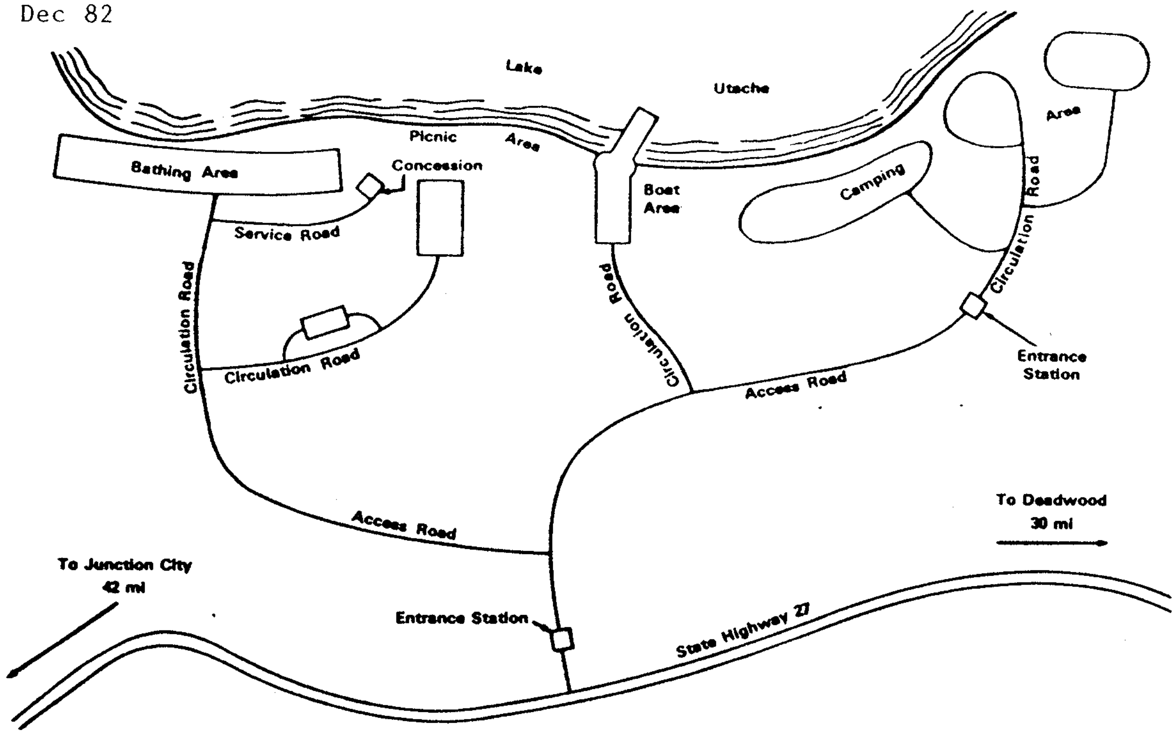


Figure 2-1 Schematic of typical recreation road pattern showing three main types of roads serving a recreation site.

Mountainous terrain may cause some vehicles towing heavy loads to operate at crawl speeds. Definitions of terrain classifications are as follows:

(a) Level terrain is that condition where sight distances are generally long or could be made to be so without major changes to the natural environment.

(b) Rolling terrain is that condition where the natural slopes consistently rise above and fall below the roadway grade line and where occasional steep slopes offer some restrictions to horizontal and vertical alignment.

(c) Mountainous terrain is that condition where longitudinal and transverse changes in the elevation of the ground with respect to the roadway are abrupt.

b. Road Classifications. Recreation road classifications are set out here for convenience of reference and to set the stage for good park road design. The recreation road is divided into three major types. These are: access road (the transition between high speed roads, and the park area) circulation road (an integral part of the recreation site or area), and the service road (the link between the high speed, access, or circulation road and special services provided by the park manager and the Government concessionaire). Figure 2-1 shows the different roads serving a recreation site with most of the outdoor recreation activities.

(1) Access Road. An access road is a road which permits vehicles to move between an existing public thoroughfare and the recreation site or area. These roads should be environmentally pleasing to serve as approaches to recreation areas. Access roads outside park boundaries may be designed more like highways, while access roads within park boundaries should be designed as recreation roads. In either case the impact on the environment should be as slight as feasible. Access roads may be two-way, two-lane roads and in some instances dividing of the lanes might become a practical application.

(2) Circulation Road. A circulation road is a road which connects with an access road or other circulation road and leads to and through recreation use areas and facilities. Circulation roads may be two-way.

(3) Service Road. The service road is used primarily for maintenance and supply vehicles within recreation areas. Service roads may also serve as public hiking/biking trails and firebreaks. Normally they will be one lane wide. Turnarounds and passing lanes should be provided where needed or as required.

c. Traffic.

(1) Importance of Traffic Data. The design of a road or any part thereof should be based upon factual data, among which are those relating to traffic. All data should be considered jointly. Cost, quality of foundations, availability of materials, and other factors have important bearing on the design, but traffic indicates the service for which the road is being built and directly affects the geometric features of design such as width, alignment, grades, etc. Traffic information serves to establish the "loads" for geometric road design.

(2) Design Traffic. The quantity of traffic for recreation roads will be derived by analyzing the road system for distribution of traffic generated by the park design load. The design load will be based on visitation anticipated on a normal weekend day during the principal recreation season with full development. The design load (vehicles perday) will be used for each recreation road classification as outlined

below in the similar way as Average Daily Traffic count is used in highway design. Design traffic will not be based on the unusually heavy traffic on a holiday weekend such as the 4th of July or Labor Day. It should be recognized that some congestion and overloading will occur on holiday weekends. The mix of vehicle types (ratio of SU:P-see paragraph 2-2d (2)) should also be estimated for each road.

d. Vehicle Characteristics.

(1) Vehicle Characteristics. The physical characteristics of vehicles including their size, maneuver patterns and the various types of vehicles used by recreationists are positive controls in geometric design. Some recreation vehicles might seem at a glance to have unique characteristics, i.e., a 30-foot long motor home. The length, width, wheelbase and turning radius are all similar to commercial trucks or buses. The motor home (RV) is used extensively for outdoor recreation experiences and are used for extended vacations rather than the weekend recreation visit. These and other trends must be studied and verified from time to time and perhaps for each major project to be sure the right design data are selected.

(2) Design Vehicle. This is a selected motor vehicle, the weight dimensions and operating characteristics of which are used to establish road design controls to accommodate vehicles of a designated type. For purposes of design, the design vehicle should be one with dimensions and minimum turning radius larger than those of almost all vehicles in its class. The heaviest and largest travel units using recreation roads are school buses, motor homes and maintenance and construction oriented vehicles such as dump trucks. Generally, their loaded weights will not exceed 10,000 pounds (total weight). A single unit truck (SU), as described in AASHTO "A Policy on Geometric Design of Rural Highways", 1965, best fits this class. (See Figure II-9 of above referenced AASHTO Policy). The SU Design Vehicle should be used for access roads, circulation roads, and service roads which will be used by buses, motor homes and/or maintenance trucks. Other roads which will be used only by passenger cars and light pickup trucks may be designed based on Design Vehicle P (See Figure II-3 of above referenced Policy for definition).

e. Capacity. Capacity will seldom govern design of recreation roads. For two-way traffic, two lanes of appropriate width will almost always accommodate traffic for Corps parks. In those rare instances where two 12' wide lanes would be inadequate, a proposal to provide more than two-lanes must be thoroughly justified in a feature design memorandum on the basis of AASHTO capacity data and approved by the Division Engineer. One-way roads of more than one lane will also require the same justification and Division Engineer approval.

f. Safety. It is imperative that the Corps' recreation roads be designed to provide safety to park participants. This should be accomplished by applying the design data set forth herein with sound professional judgment to recreation road needs.

g. Cost. Road construction consumes a large percentage (25 percent and more) of funds available for providing recreation facilities and also for project maintenance. Considerable design effort is necessary in getting the most road for the dollar initially, while at the same time giving full consideration to recreation and environmental values, maintenance, safety and life cycle cost.

2-3. Elements of Design.

a. Design Speed. The design speed of a roadway is defined as "the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern" (AASHTO, 1965). Design speed should be selected with respect to the character of the terrain and the level of roadway which is to be constructed. Current design standards are generally based on design speeds ranging between 30 and 80 miles per hour. For recreational roadway systems, however, 20 to 30 mile per hour designs should be considered far more suitable and economic. The use of a reduced design speed may provide for the reasonable reduction of other design parameters related to the design process, e.g. sight distances.

(1) General. Table 2-1 through 2-3 give the design speed for access and circulation roads as discussed in road classifications set out in paragraph 2-2.

Table 2-1
SUGGESTED DESIGN SPEEDS (MPH)
Access Roads Outside Park Boundaries Longer Than One Mile
Connecting a Public Road*

Type of Terrain	Traffic Brackets for Design Control-Vehicles Per Day (VPD) 0-50	50-250	250-400	400-750	750-1000	over 1000
Level	40	40	50	50	50	50
Rolling	30	30	40	40	40	40
Mountainous	20	20	20	30	30	30

*Design speeds for this type of access road should adhere to the principles of recreation road design rather than highway design standards. Design speeds should be selected which will begin to make the transition from highways to recreation roads. There is no need to use design speeds greater than that which will be permitted on this type of road by legal or regulatory speed limits.

Table 2-2
SUGGESTED DESIGN SPEEDS (MPH)
Short Access Roads Outside Park Boundaries and
Access Roads Within Park Boundaries

Reaches of Significant Length through Undeveloped Lands	Reaches through Developed Access Areas and Sites
40 mph maximum	20 mph maximum

Table 2-3
SUGGESTED DESIGN SPEED (MPH)
Circulation Roads

Reaches of Significant Length through Undeveloped Lands	Reaches through Developed Areas and Sites
30 mph maximum	20 mph or less

(2) Service Roads. Use the maximum suggested design speed that terrain permits economically. The suggested range of design speeds is from 20 to 40 mph with a maximum of 15 mph through developed sites and areas.

b. Sight Distance.

(1) Passing sight distance. Provision of the minimum passing sight distances indicated in Table 2-4 is secondary to fitting the road to the terrain, preservation of natural resources, minimizing earthwork and safety of recreation users scattered in sites and areas. The distances traversed by recreation roads are relatively short and do not merit much effort or cost to provide safe passing sight distances; however, when passing is not permitted, "No Passing" signs and markings should be provided in accordance with American National Standards Institute (ANSI) D6.1-1978, "Manual on Uniform Traffic Control Devices-For Streets and Highways". Passing sight distance need not be provided on recreation roads except that it should be at least considered on long access roads outside parks.

(2) Stopping sight distance. Minimum safe stopping distance for access roads should be provided as indicated in Table 2-4. Adjustments might have to be made in the case of circulation roads where integrity of site values (recreation values) might be compromised. Posting of safe speeds might be the designers choice in these cases remembering that

Table 2-4

MINIMUM SIGHT DISTANCES IN FEET

Design Speed, mph	20	30	40	50
Stopping sight distance				
Minimum Stopping Sight Distance, feet	150	200	275	350
K Value for:*				
Crest vertical curve	16	28	56	85
Sag vertical curve	24	35	55	75
Desirable Stopping Sight Distance, feet	150	200	300	450
K Value for:*				
Crest vertical curve	16	28	65	145
Sag vertical curve	24	35	60	100
Passing sight distance:				
Passing distance, feet 2-lane	--	--	1500	1800
K Value for:*				
Crest vertical curve	--	--	686	985

*NOTE: K value is a coefficient by which the algebraic difference in grade may be multiplied to determine the length in feet of the vertical curve which will provide minimum sight distance.

generally speeds on circulation roads are below 30 mph. Figure 2-2 shows data for stopping sight distances at intersections for wet pavements with increases and decreases for percent grade. Professional judgment should be applied in mountainous terrain and terrain between mountainous and rolling as to whether minimum stopping sight distance should be provided. Proper signing might have to suffice in lieu of extreme grading to attain engineering integrity of the road design.

The need for sight distance across the inside of horizontal curves must not be neglected where there are sight obstructions such as walls, cut slopes, wooded areas, buildings, etc.

(3) Measuring sight distance. Criteria for measuring distance, both vertical and horizontal, are as follows: for stopping sight distance, height of eye, 3.75 feet and height of object 0.5 foot; for passing sight distance, height of eye, 3.75 feet and height of object, 4.5 feet.

(4) Special application of passing sight distance. Passing sight distance is not given for design speeds of 20 and 30 mph because where

factors indicate that speed that slow is required on recreation roads, passing is undesirable and design data is not needed. Roads designed for 20 and 30 mph are circulation roads inside developed areas with activity facilities nearby, i.e. picnicking and camping.

(5) Special application of minimum sight distance. Where crest vertical curves and horizontal curves occur at the same location in rolling terrain, greater than minimum sight distance should be used in the design to assure that the horizontal curve is visible as drivers approach. When this condition occurs in mountainous terrain proper signing of safe speed and extent of horizontal curve should be used to indicate safe driving conditions and speed.

c. Horizontal Alignment.

(1) Design philosophy. Long tangents should not be used in park road design. The horizontal and vertical alignment should respect the terrain, so that the road is laid lightly on the land. In deciding upon road location, maximum emphasis should be given to interpretive and scenic values. The design and location of roads, trails, walks and overlooks should be interrelated to permit the visitors to enjoy the park visit more thoroughly with as much freedom as possible in the manuver of their automobiles, pedestrian travel and other forms of park travel. Heavy

Minimum Stopping Sight Distance for Wet Pavements									
Highway Design Speed	Assumed Speed For Wet Condition	Minimum Stopping Sight Distance For Wet Pavement. Grades To 2%		Correction for Stopping Sight Distance for Wet Pavement					
				Decrease For Upgrade			Increase For Downgrade		
		Computed	Rounded	+3%	+6%	+9%	-3%	-6%	-9%
M.P.H.	M.P.H.	Feet	Feet	Feet	Feet	Feet	Feet	Feet	Feet
30	28	176	200		10	20	10	20	30
40	36	263	275	10	20	30	10	30	50
50	44	369	350	20	30		20	50	
60	52	491	475	30	40		30	80	

Figure 2-2. Minimum Stopping Sight Distance for Wet Pavement

earthwork in cut and fill sections should be avoided. In effect the road should be molded to the terrain through which it is passing. Monotony is relieved, and maximum advantage is taken of park values by changes in elevation and by developing viewpoints and overlooks, as well as by providing close-range views of near scenes. Curving alignment offers constantly changing views of the scenery.

(2) Layout. Curving or winding alignment is preferred for recreation roads. Park roads should be aligned with curves, often compound, and connected with relatively short tangents or spirals, or both. Figure 2-3 shows curving alignment for recreation roads. It is desirable to use tangents, curves and spirals to define the alignment of highways

Figure 2-3 Curving Alignment for Recreation Roads

with appreciable traffic; however, for recreation roads with low traffic, the alignment can be (a) "eyeballed" or (b) driven in with a passenger vehicle or light pickup truck. When either method (a) or (b) is used for determining alignment, it should be staked and referenced (and/or witness staked) in the field with appropriate notation provided on the plans and as-built drawings. The alignment for such minor roads can be sketched on the plans and the measured length shown for bidding and payment. Deflection angles at points of intersection of up to five degrees may be used without horizontal curves inside parks. Recreation roads should be aligned to best accommodate the design of supporting facilities such as boat launching ramps, camping facilities, picnic facilities, overlooks, beaches, and their attendant parking facilities. Recreation roads should be located to preserve the integrity of the scenic values of the project, e.g., reservoir shoreline, bogs and natural rock outcroppings.

(3) Roads in reservoir areas. Generally roads should be located outside areas that are likely to be affected by shoreline erosion. When such areas cannot reasonably be avoided, shoreline protection (i.e., riprap) should be included. Access roads to camping areas that can be flooded, particularly when rapid pool rises can be expected, should be high enough that they will provide safe egress once the danger of rising water is readily apparent.

(4) Maximum curvature. Depending on the maximum superelevation value selected by the designer, the maximum curvature for different design speeds is shown in Table 2-5.

(5) Superelevation. Where ice and snow are factors, a superelevation rate of about 0.08 is a logical maximum to minimize slipping across the road when stopped or when attempting to start from a stopped position. From Table 2-5 above, it can be seen that there is little to be gained in greater permissible maximum degree of curve by increasing the maximum "e" above 0.08. Greater rates of superelevation tend to cause excessive inward friction required to drive slowly around the curve, a condition resulting in erratic vehicle operation. For this reason, it is recommended that a maximum superelevation rate of 0.08 normally be used. Where low speed operation will prevail, a low maximum rate of superelevation is appropriate. For additional guidance on standards for superelevation, follow the practice of the local highway department or AASHTO policy for rural roads. The extent and nature of applying superelevation in recreation road design should be tempered with the knowledge of the need for the road to be open during extreme winter conditions and the actual posted speed intended. Roads in camping areas are subject to not more than 15 mph posted speeds. Many other park areas need to have 15 mph speeds posted. The need for superelevation should be tempered with this knowledge. Road designers need to become fully informed as to how the area served by the road will be managed.

(6) Superelevation runoff. Superelevation runoff is the length of roadway needed to accomplish the change in cross slope from a normal crown section to a fully superelevated section. Minimum lengths of runoff are shown in Table 2-6. Adjustments in design runoff lengths may be necessary for smooth riding, surface drainage, and good appearance. For low speed center-crowned roads, removal of the adverse crown in the outside lane to provide a "shed" transverse grade sloping to the inside of the curve may be adequate for the runoff required. On curves with spirals the superelevation runoff is effected on the spiral. On curves without spirals, from 60 to 80 percent of the length of runoff should be located on the tangent. Smoothly rounded edge of pavement profiles are the desired end in design of superelevation runoff, rather than exactness in fitting the above guide values. For additional design details, follow the practice of the local highway department or AASHTO policy.

(7) Minimum desirable radii. Figure 2-4 shows minimum desirable radii for very low speed (5-10 mph), low design traffic recreation road curve.

(8) Pavement widening on Curves. Pavement widening need not be provided at horizontal curves in recreation roads with radii to the inside edge of surface greater than 100 feet because of the local nature of the roads, reduced vehicle operating speeds, relatively low traffic volumes and the absence of large commercial trucks. Because recreation roads should curve to fit the terrain it is more desirable in rolling to mountainous rough terrain from the standpoint of vehicle operation, constructability and appearance to make the normal road surface width about two feet wider than the practicable minimum than to widen first on one side and then the other. In level terrain flatter curves can be used. It is significant to note that the AASHTO makes no recommendation for widening for local roads. Widening should only be provided in recreation roads when it is crucial to safe vehicle operation. Also, see paragraphs 2-4b and 2-4d for extensive design data for pavement widening of recreation roads. In the unusual instances where widening on curves must be used, follow the standard of the local highway department or the design policies of the AASHTO.

(9) Design without superelevation. Frequently in parks with considerable irregularity in terrain, the distance between reverse curves will be too short to permit adequate runout of superelevation for a reversal in the cross slope of the road surface. The use of superelevation in extremely curving roads as opposed to normal center crown cross sections adversely affects constructability and control of grading. Some park road designers prefer to design circulation and service roads, where terrain and soils permit, with the cross slope

Table 2-5

MAXIMUM DEGREE OF CURVE AND
MINIMUM RADIUS FOR DIFFERENT VALUES
OF MAXIMUM SUPERELEVATION

Design Speed	Maximum e*	Minimum Radius (Rounded)	Max. Degree of Curve (Rounded)
MPH		Feet	Degrees
20	.06	115	50.0
30	.06	275	21.0
40	.06	510	11.5
50	.06	830	7.0
20	.08	110	53.5
30	.08	250	23.0
40	.08	460	13.0
50	.08	760	8.0
20	.10	100	58.0
30	.10	230	25.0
40	.10	430	14.0
50	.10	690	9.0
20	.12	95	63.0
30	.12	215	27.0
40	.12	400	15.0
50	.12	640	9.0

*Note: e = rate of roadway superelevation, foot per foot.

approximately parallel to the natural cross slope of the existing ground (without roadside ditches). In no case should the cross slope be less than ¼-inch per foot nor more than ½-inch per foot. Omission of superelevation may be permitted provided that after roads have been constructed, but before they are opened to the public, the maximum safe speed for negotiating curves is determined and posted with signs.

Table 2-6

MINIMUM LENGTH FOR SUPERELEVATION
RUNOFF FOR 2-LANE PAVEMENTS

Superelevation Rate Foot per foot	L-Length of runoff in feet for design speed, MPH, of:			
	20	30	40	50
.02	50	100	125	150
.04	50	100	125	150
.06	50	110	125	150
.08	50	145	170	190
.10	50	180	210	240
.12	50	215	250	290

Preferably this should be accomplished in cooperation with the state highway department. See the discussion of use of the ball bank indicator on page 154 of AASHTO, "A Policy on Geometric Design of Rural Highways", 1965. If the safe speed cannot be determined in connection with the state highway department, it will be determined by other suitable means, such as test driving in a vehicle typical of the design vehicle. When a passenger car is used it should be towing a rather long heavy trailer and when an SU type vehicle is used it should have a rather high center of gravity. If the maximum safe speed for negotiating a curve is determined to be less than the established speed limit (established in cooperation with the appropriate enforcement authority) for the reach of road, appropriate warning signs should be installed. ANSI D6.8 sign 2C-5 Curve Sign (W1-2), 2C-7 Reverse Curve Sign (W1-4), or 2C-8 Winding Road Sign (W1-5) as appropriate should be used at the top of the sign assembly. A 2C-35 Advisory Speed Plate (W13-1) should be mounted on the same assembly just below the appropriate curve warning sign to indicate the maximum safe speed for negotiating the curve or curves.

d. Vertical Alignment - Profiles.

(1) Design philosophy. Profile and horizontal alignment go hand in hand. A good profile cannot be established on an alignment which has not been wisely designed to most advantageously traverse the terrain. In usual road design the profile is established with the objective of

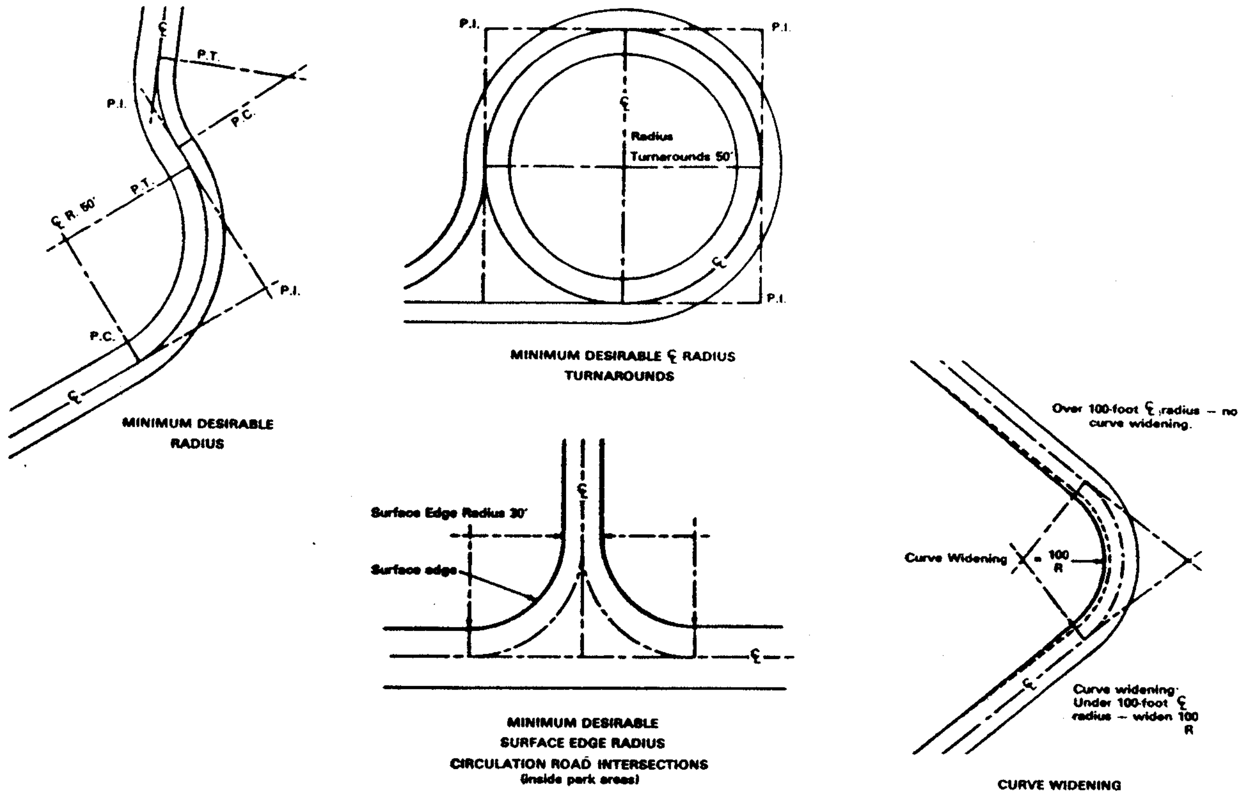


Figure 2-4 Minimum Desirable Radii for Recreation Roads

balancing cut and fill within economical haul distance. Recreation roads are different. For a traffic way that blends and flows with the terrain as well as provides a smooth transition from the paving to the roadside for errant vehicles, the vertical alignment should follow the existing grade as closely as possible. When suitable borrow material is economically available, consideration should be given to building the roadbed slightly above natural ground rather than trying to balance cut and fill. Often this will provide better drainage, create less disturbance of the environment, be less costly, and create less problems from an erosion control standpoint. All borrow areas used in this manner should be located to provide the least disturbance to the environment, preferably out of the view of visitors. When economically feasible, borrow should be taken below the elevation of a conservation or permanent pool. In mountainous terrain it may be necessary to exceed the desirable maximum grades because the cost of doing otherwise would be prohibitive and the environment severely harmed. When it is necessary to exceed the desirable maximum grades, the reaches should be kept as short as feasible and combinations of steep grade and horizontal curves should be avoided, as much as possible. Consideration should be given to the dangers that steep grades pose when traversed by light vehicles towing trailers.

Steep grades are particularly undesirable for gravel-surfaced roads because they are unsafe when wet and the gravel tends to be washed away. Figure 2-5 illustrates good vertical alignment of roads in park areas.

Figure 2-5 Vertical Alignment of Roads

(2) Maximum grades. Table 2-7 shows the desirable maximum grades for different types of terrain and design speeds in percent.

Table 2-7

MAXIMUM GRADES*

Type of Terrain	Design Speed MPH			
	20	30	40	50
Flat	7	7	7	6
Rolling	10	9	8	7
Mountainous	12	10	10	9

*Note: For roads with design traffic below 250 or where terrain is such that the grades shown would require cut and/or fill that would be excessive for a park road, grades of relatively short lengths may be increased up to 150 percent of the values shown while observing the cautions in paragraph 2-3d(1) above.

(3) Vertical curves. Vertical curves are used to effect gradual change between tangent grades. They should be simple in application and should result in a design which is safe, comfortable in operation, pleasing in appearance, and adequate for drainage. The major control for safe operation on crest vertical curves is the provision of minimum stopping sight distances for the design speed. In any design the sight distances should be consistent with the terrain and conservation of the environment. Considerations of comfort require that vehicular rate of change of grade be kept within tolerable limits. This is most important in sag vertical curves where gravitational and vertical centrifugal forces act in the same direction. Appearance also should be considered. A long curve has a more pleasing appearance than a short one which may give the appearance of a sudden "break" in the profile due to the effect of foreshortening. Simple parabolic curves should be used on recreation roads. Vertical curve data including K values are given in Table 2-4 under paragraph 2-3b(2) above, entitled Minimum Sight Distances in Feet. In recreation road design, minimum sight distances might be the rule instead of the exception and provision of prescribed appropriate markings and signs in accordance with ANSI D6.1-1978 can provide the proper safety precautions.

(4) Grades at intersections. Where intersections occur on road sections with moderately steep grades, it is desirable to reduce the gradient through the intersection in all legs of the intersection. Such a profile change is beneficial for all vehicles making turns and reduces potential hazards.

e. Combination of Horizontal and Vertical Alignment. Design of a recreation road is an art in three dimensions embodying many controls and elements, all interrelated. The following are excerpts from the AASHTO "A Policy on Geometric Design of Rural Highways", 1965 and are applicable to recreation road design, but with more emphasis on environmental values and less emphasis on efficiency in moving traffic rapidly.

"COMBINATION OF HORIZONTAL AND VERTICAL ALINEMENT"

"Horizontal and vertical alinement should not be designed independently. They complement each other, and poorly designed combinations can spoil the good points and aggravate the deficiencies of each. Horizontal alinement and profile are among the more important of the permanent design elements of the highway, for which thorough study is warranted. Excellence in their design and in the design of their combination increase utility and safety, encourage uniform speed, and improve appearance, almost always without additional cost.

"ALINEMENT COORDINATION IN DESIGN"

"Coordination of horizontal alinement and profile should not be left to chance but should begin with preliminary design, during which stage adjustments can be readily made. While a specific order of study for all highways cannot be stated, a general procedure applicable to most facilities can be outlined.

"The designer should utilize working drawings of a size, scale, and arrangement so that he can study long, continuous stretches of highway in both plan and profile and visualize the whole in three dimension. Working drawings should be of sufficiently small scale, generally 1 in. = 100 ft. or 1 in = 200 ft., with the profile plotted jointly with the plan. A continuous roll of plan-profile paper usually is suitable for this purpose.

"After study of the horizontal alinement and profile in preliminary form, adjustments in each, or both, can be made jointly to obtain the desired coordination. At this stage the designer should not be concerned with line calculations, other than known major controls. The study should be made largely on the basis of a graphical analysis. In doing so the use of splines, highway curve templates, ship curves, and straightedges are convenient in projecting both the horizontal alinement and the grade line. The criteria and elements of design covered in this and the preceding chapter should be kept in mind. For the selected design speed the values for controlling curvature, gradient, sight distance, superelevation runoff length, etc., should be available and checked graphically. Design speed may have to be adjusted during the process along some sections to conform to likely variations in speeds of operation where noticeable changes in alinement characteristics may occur. All aspects of terrain, traffic operation, and appearance can be considered and the horizontal and vertical lines adjusted and coordinated before the costly and time consuming calculations and the preparation of construction plans to large scale are started.

"The coordination of horizontal alinement and profile from the viewpoint of appearance can be accomplished visually on the preliminary working drawings. Generally this results in a satisfactory product when done by an experienced designer. This means of analysis may be supplemented by models of perspective sketches at locations where the effect of certain combinations of line and grade are questionable."

f. Drainage and Erosion Control. The importance of good drainage, both surface and subsurface cannot be overemphasized. Inadequate drainage, erosion control and overloading are the three greatest causes of road failures. Some general guidance for the design of drainage and erosion control design is given in the following sub-paragraphs.

(1) Design drainage structures to blend into the surrounding landscape rather than intrude upon it. Also use drainage grates that will not divert bicycle wheels when passed over. See Figure 2-6.

(2) Avoid long ditches along roadways which tend to accumulate large flows and require big ditch sections. The use of subdrains, catch basins, water bars, drainage dips, free draining embankment slope protection, slope seeding and outsloping road surfacing should be considered in the design.

(3) To the extent feasible, use natural materials such as stone for velocity and erosion control to avoid the high velocities of concrete chute structures. More specific guidance on roadway ditch design is presented in paragraph 2-4e and on drainage structure design in paragraph 2-6.

g. Landscape Development. Landscaping should be used for aesthetics, erosion control and to aid safety of drivers and pedestrians. Landscaping of recreation roads can be accomplished by vegetation, by shaping land forms, and by location of the road itself. Landscape development should be an element of the recreation road design.

Figure 2-6 Special Provision for Drainage

h. Roadside Turnouts, Driveways and Roadside Controls. These functional elements need to be considered in the design of recreation roads. Their frequency, location in relation to scenic features and recreation facilities, where they occur in relation to traffic volume and the safety of the user, and how well they serve the recreationist for enjoyment in the park visit are all important considerations in roadside control. The efficiency and safety of a recreation road depend greatly upon the amount and character of roadside interference most of which originates in recreation vehicle movements to and from the park and areas within the park. Overlooks and vistas, intersecting roads leading up to specific activity areas, off-road parking access, the camping spur, fee collection and check-in stations are examples of the roadside functional elements to be considered.

i. Utilities. Utilities such as power lines, telephone, water, gas and sewerage mains, which occupy or cross the road right-of- way, should be considered in location and design of the road. Normally, on new construction, no utility should be situated under any part of the pavement, except where it must cross the road. For such cases the utility should be placed in a pipe sleeve. Preferably underground utilities should be located outside the roadway to avoid any disturbance to traffic during utility maintenance activities.

j. Signs and Markings. Signs and markings are directly related to the design of the road and are features of traffic control and operation which the designer must consider in geometric layout of the work. Signs on project lands should be in accordance with EP 310-1-6, Chapter 4, Signage. Signs not on project lands should be coordinated with the appropriate state, county, or local authority. In addition signs, markings, and other traffic control devices pertaining to recreation roads should be provided in accordance with the Manual on Uniform Traffic Control Devices for Streets and Highways, ANSI D6.1-1978, U.S. Department of Transportation, Federal Highway Administration. Signs required to properly direct and warn drivers should be provided for public safety. Center line markings, no passing markings and pedestrian and cycle crossing markings are also stressed. Also see discussion on signing and marking as geometric design elements in AASHTO "A Policy on Geometric Design of Rural Highways", 1965 for additional guidance.

k. Lighting. Normally, lighting will not be provided except to improve safety at particular hazards or for security reasons. Hazards which would require lighting should be avoided to the extent possible by prudent road design and recreation facility management techniques and practices. Low nighttime traffic volumes generally prevailing in parks and low speed operation imposed in developed sites and areas should usually obviate the need for lighting of roads. When lighting is necessary, luminaries should be placed on standards high enough to minimize the effect of glare and to prevent vandalism. Standards should be located back of the horizontal obstruction clearance. Lighting in developed areas for roads should be coordinated with any other lighting, such as for campgrounds. Break-away standards should be used along roadways. For additional discussion of lighting, see AASHTO policy.

2-4. Cross Section Elements.

a. General. The design elements covered in this paragraph are illustrated on Figure 2-7 and the terms used conform with those on the illustration. The desirable range of rate of normal cross slopes is given in Table 2-9.

b. Width.

(1) Access roads. The minimum surface widths should be as given in Table 2-8. The widths given in the table have been adjusted from normal designs. These adjustments are made for the following reasons. First, the surfaced lanes of recreation roads are increased to provide a greater margin of safety and to reduce maintenance of the pavement edge and/or the shoulder at the pavement edge. This widening helps distracted drivers to maintain control of the many types of recreation vehicles especially those pulling trailers. Second, the park area can be considered a destination point and drivers need a wider pavement for safe operation of vehicles under congested conditions. Third, it is important in the interest of safety to paint a white stripe along the very edge of the pavement or one to two feet inside from that edge depending on the amount of pavement widening. See Figure 2-8.

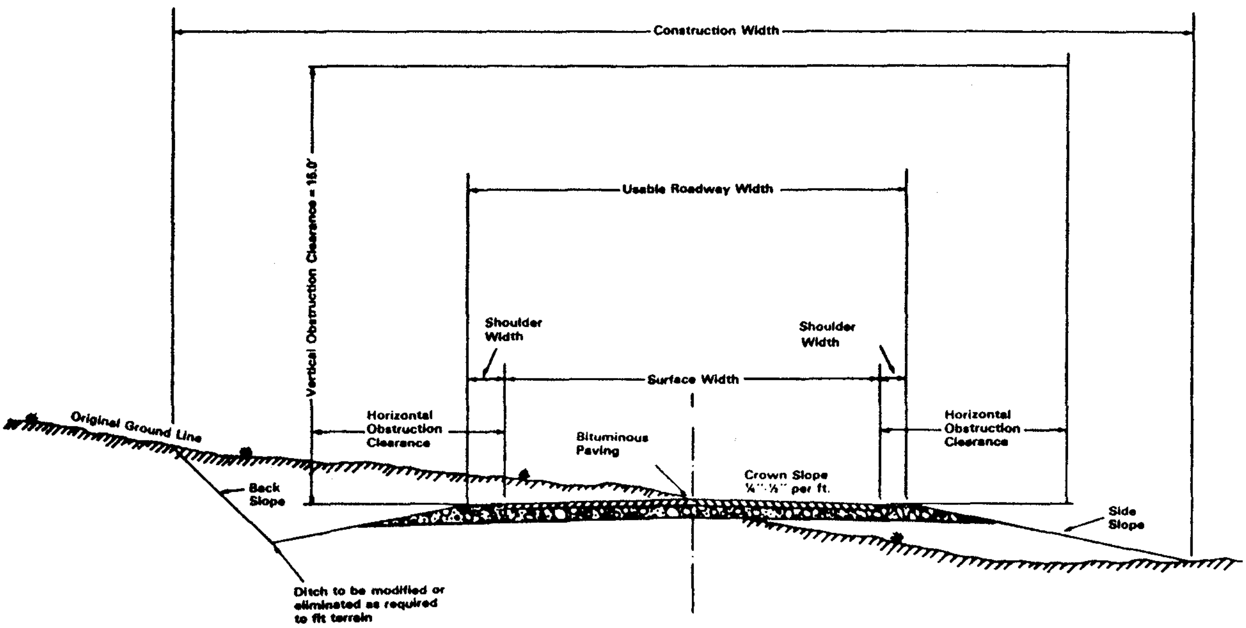


Figure 2-7 Cross Section elements for recreation roads

(2) Circulation Roads.

(a) Two-way circulation roads. Surface width should normally be 22-feet. Roads with design traffic of over 250 VPD and when design vehicle SU is used, surface width may be 24-feet wide. Where design vehicle P is applicable and design traffic is less than 250 VPD, 18-foot wide surface may be used. Minor short circulation roads and loops may also have 18-foot wide surface. When in doubt, use 20-foot surface.

(b) One-way circulation roads. Surface width should be 12-feet except for long roads with very sharp curves, through large campgrounds, where width should be 14-feet wide.

(3) Service roads. When surfaced, the surface width should be 10 feet. The type of surfacing provided should meet the need of access to the service facility (including O&M requirements). Surfacing of service roads might be economical for short distances to aid erosion control and other drainage problems.

Table 2-8

MINIMUM SURFACE WIDTH - TWO LANE ACCESS ROADS

	Surface Width in Feet for Design Traffic of:				
Design Speed, MPH	VPD (Vechicles per day) Less Than 50	VPD 50-250	VPD 250-400	VPD 400-750	Over 750 VPD with peaks
20	22	22	24	24	24
30	22	24	24	24	24
40	22	24	24	24	26
50	22	24	24	24	26

Table 2-9

NORMAL PAVEMENT CROSS SLOPES

Surface type	Cross Slopes	
	Inch per foot	Foot per foot
High	1/8-1/4	.01-.02
Intermediate	3/16-3/8	.015-.03
Low	1/4-1/2	.02-.04
Unsurfaced	1/2-1	.04-.08

c. Curbs. There are few applications of curbs in design and construction of recreation roads. They should be used only when needed for one or more of the following purposes. (1) to control drainage, (2) to confine vehicles to the pavement, or (3) to direct or channelize traffic. When curbs are used they should be designed in accordance with paragraph 3.3.3.3 of TM 5-822-2. In addition to the designs shown in CE Standard Drawing No. 40-17-02 the following designs may also be used: (1) extruded or slip-formed asphaltic concrete or Portland cement curb, (2) when direction of drainage is away from the curb, a free standing, partially buried more or less rectangular shaped wall type concrete, masonry or reinforced concrete curb with the exposed traffic side slightly battered away from the road surface, (3) pre-cast wheel stops and (4) a low flat, cast in place curb on grade, more or less rectangular in cross section with its width at least twice its height. Where a barrier only is needed, logs, railroad ties, masonry walls or other equivalent material may be used so long as it does not impose an increased hazard to vehicles.

d. Shoulders.

(1) Access roads outside park boundaries. Shoulders on access roads outside park boundaries should be designed to the standards of the highway agency who will be responsible for the operation and maintenance of the constructed roadway. All other access roads (those inside park boundaries) should be designed in accordance with the data given below.

(2) Access roads and circulation roads inside park boundaries. Because of the purpose and nature of the recreation road and the mood generated by the terrain, shoulders for those roads inside park boundaries serve modified purposes. The purpose of shoulders for this type of road is needed to protect pavement edge and provide transition between the pavement and fill or cut slopes. Temporary storage of disabled vehicles is not important on the usually short length of road, because of the slow speed of traffic, and the length of time, both weekly and daily the road is in use. Disabled vehicles can be tolerated better in recreation areas, therefore, complete off-the-road temporary vehicle storage is not critical. Preservation of the natural resources becomes very important in recreation areas and must be dealt with while designing park roads.

(3) Importance and functions. Because recreation areas attract many types of vehicles, it seems prudent to reduce the usual road shoulder for recreation roads and increase the pavement width according to the design speed and extent of use. An additional characteristic of the recreation road, i.e., curving alignment, also adds credence to the reduction of shoulder width and increasing pavement width principle. Pavement widening is practiced for the ordinary highway at curves. Shoulders on all recreation roads should be stabilized to provide lateral support for the pavement, facilitate drainage of the pavement (both surface and subsurface), reduce maintenance cost, and provide greater safety for visitors. See the discussion on importance of stabilizing shoulders beginning on page 238 of AASHTO, "A Policy on Geometric Design of Rural Highways, 1965. The stablization need not be extended at full depth for

the entire shoulder width. A feathered edge cross slope may be used for all or part of the shoulder width. A shoulder material that will provide stabilization and support a stand of grass is desirable. Shoulder stabilization to provide traffic support and support the growth of vegetation may require some additional cost but it is justified in climates that will sustain growth. The shoulder design should provide sufficient depth to allow root development and to sustain the vegetation. Placing a thin layer of soil over a sterile base course on the shoulder is not desirable for traffic support or for sustaining vegetation. See the discussion on turfed shoulders on page 239 of the AASHTO policy referred to above. For trafficability of shoulders give appropriate consideration to camping and boat trailers of considerable weight on small wheels.

(4) Shoulder width.

(a) Access roads and circulation roads. Shoulders for access and circulation roads for most recreation areas should be 2 feet. In some cases a greater width might be required for safety.

(b) Service Roads. Surfaced roads should have 1-1/2 feet wide shoulders.

(c) Shoulder with guard rail. Where a guard rail is used the shoulder should be increased 1 to 2 feet to permit setting the guard rail farther from the edge of the surface. Figure 2-8 shows a typical example of good shoulder width with a guardrail on an access road.

(5) Shoulder cross slopes. The desirable range of cross slopes is given in Table 2-10 for types of shoulder surfaces.

e. Slopes, Drainage Ditches, Channels and Erosion Control. These should be designed for minimum grading and clearing, safe and pleasing roadsides, and to present the least difficulty in erosion control. See discussion of these design elements in AASHTO policy. There is a conflict between two desirable features for ditches and slopes. These are:

(1) Slopes should be relatively flat and ditches shallow for safety and to blend with the terrain.

(2) The total width of the construction cross-section should be narrow to reduce clearing and minimize the scar caused by construction. This requires judgment to develop a good overall design. In cut sections it is recommended that the sideslopes be 6:1 (6 horizontal on 1 vertical)

and the backslope 3:1 (3 horizontal on 1 vertical). With these slopes, unforeseen ditch erosion is more likely to cut into the backslope which is more desirable than cutting into the sideslope. In rock cuts the backslope may be as steep as the rock characteristics permit. Minimum ditch depth to be shown on typical sections for cut should be 1 foot in soil and 6 inches in rock. These ditch depths should be measured from top of subgrade at shoulder points or edge of additional pavement to bottom of ditch. Consideration for deeper minimum depth ditches should be based on the following: (a) where necessary to intercept subsurface drainage or seepage; (b) in the northern latitudes where heavy snowfall

Table 2-10

SHOULDER CROSS SLOPES

	Shoulder cross slope (No Pavement edge curbs)	
Type of surface	Inch per foot	Foot per foot
Bituminous	3/8-5/8	.03-.05
Gravel or crushed stone	1/2-3/4	.05-.06
Turf	1	.08

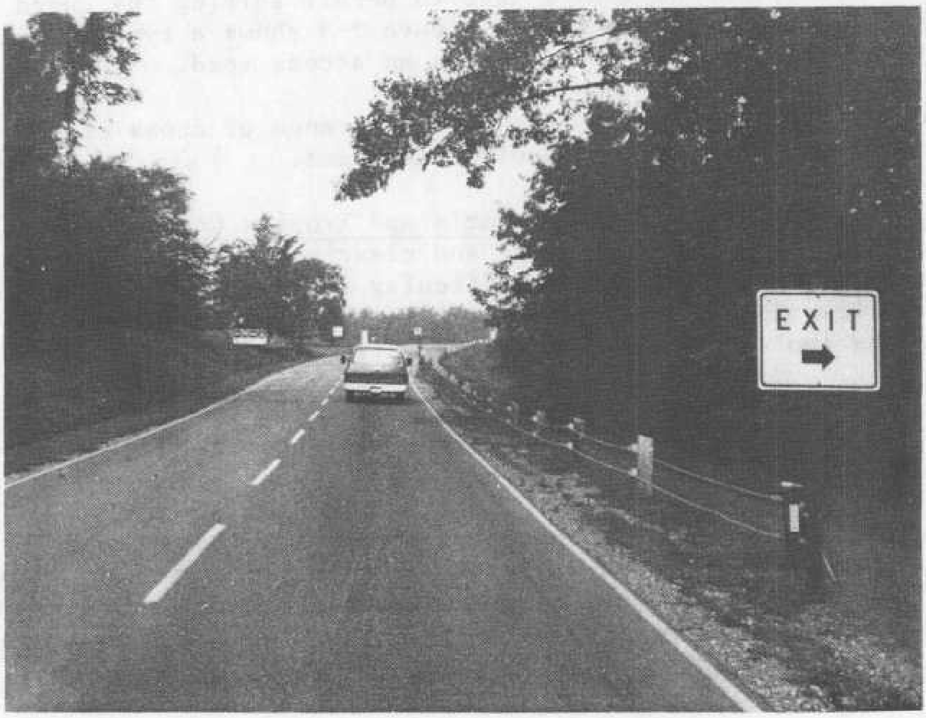


Figure 2-8 Cross Section Showing Pavement Striping, Shoulder and Guardrail

tends to block ditches, impeding runoff so as to cause damaging saturation of the pavement or subgrade; and (c) where deeper ditches will reduce overall cost where freezing governs pavement design thickness. Ditches should be routed and slopes warped where feasible to save desirable trees and other landscape features. Ditch bottoms should be sized and graded to carry runoff at non-erosive velocities when feasible. When erosive velocities will occur, erosion control measures should be provided. Fill side slopes should be 4:1 or flatter for rolling terrain. It is generally accepted that side slopes of 4:1 are reasonably safe and very often can be provided at less cost than the cost of guardrail. General Motors Proving Grounds tests indicate that side slopes 6:1 provide insurance against overturning even under adverse conditions. Interceptor ditches, dikes or terraces should be provided where needed to intercept runoff and conduct it away from slopes at non-erosive velocities. Roadside ditches on the upstream side of roads should be relieved with culverts across the road at intervals spaced so as to prevent excessive erosion of the upstream ditches. Ditches and channels should be designed for hydraulic efficiency by customary Corps hydraulic design criteria to accommodate runoff. Proper erosion control measures should be provided as needed, designed in accordance with customary Corps criteria. Drainage and erosion control should be designed in accordance with TM 5-820-4, Drainage and Erosion Control; Drainage for Areas Other Than Airfields. Additional sources of information on recreation road drainage and erosion control are the various state highway manuals and the Soil Conservation Service design. These aids may be used when they are more suitable for the prevailing conditions.

f. Grading. Design of grading should give consideration to roadside safety and aesthetics. Transitions between slopes, and slopes and natural ground should be rounded and warped as required for safety and to blend with the surroundings. Vegetation can usually be restored even though it may take considerable time and expense, but unsightly land forms left at the end of construction usually are difficult and costly to correct. See Figures IV-3 and IV-4 of AASHTO, "A Policy on Geometric Design of Rural Highways", 1965 for rounding of typical cross sections. Figure 2-9 shows minimum grading for a recreation road. Grading should be as light as feasible.

g. Obstruction Clearance. Obstruction clearance is the distance to be provided, measured from the edge of the (paved) road surface, which should be free of obstructions hazardous to vehicles if struck by them. Obstructions include structures, trees, poles, utility features, and standards which are not of yielding, break-away or frangible type including sign supports. Again recreation road classification must be given full consideration in determining application of the guidance set out here. As classification of the road and the intended use thereof meets with the activity area, i.e., picnicking and camping, obstruction clearance becomes less and less important and integrity of the environment begins to have stronger demands on how obstruction clearance is applied.

Figure 2-9 Grading for Recreation Roads in Activity Areas

(1) Horiz ntal. The horizontal clearance is measured as shown on Figure 2-7 from the edge of the road surface. In the obstruction clearance width, the maximum slope (shoulder or side slope) should not exceed 6:1 (6 horizontal to 1 vertical). Metal beam guardrail or other highway department standard devices may be required at places along the higher speed (40 mph or more) access road to protect vehicles where ususual conditions or economics restrict the clearance that can be provided. Maintenance of the integrity of obstruction clearance along roads inside activity areas must be judged on the merits of safety involved and serving park aesthetics at the same time. Abrupt changes in type of road (from 40 to 50 mph access road to 20 or 30 mph circulation road) thus causing hazardous conditions should be avoided because of the abrupt changes in horizontal obstruction clearance that could occur. Minimum horizontal obstruction clearances should be as given in Table 2-11.

(2) Vertical. For roads which will be used only by passenger cars (Design Vehicle P) the minimum vertical clearance should be 10'. For roads designed for Design Vehicle SU the vertical clearance should be 15'.

h. Crosswalk. Pedestrian walks crossing roads (cross walks) should be signed and marked in accordance with ANSI 6.1-1978, particularly paragraphs 3B-13 and 2C-33. Chapter 5 of this manual, gives a discussion on walks and Chapter 6 discusses trails and trail crossings of roads.

Table 2-11

MINIMUM HORIZONTAL OBSTRUCTION CLEARANCE*

	Design Speed (MPH)		
Road Classification	20 or less	30	40 or more
Access	10'	10'	16'
Circulation	Edge of widened Pavement +2'	Edge of widened Pavement +4'	-
			-
Service	-	-	-

*On a case by case basis there may be times when these distances should be waved in the interest of park aesthetics. Users should enjoy the surroundings within a park with caution since both safety and pleasure are to be served.

i. Guardrails and Delineators.

(1) General. Guardrails are used where vehicles accidentally leaving the highway would be subjected to hazard. Generally, such hazards are fixed objects along the pavement edge, fills on steep grades, long through fills, or fills on sharp curvature, but other points equally hazardous are along water courses, bodies of water, escarpments, along deep ditches in cuts (particularly with rock exposed) and similar locations. The more dangerous points along a highway are obvious from the plans, but the overall need for guardrails is best determined by field inspection as the grading nears completion. Installation should be made before the highway is opened to traffic.

(2) Guardrails on fills. The need for guardrails on fills is definitely related to the slope. Generally they may be omitted where it is practicable to provide slopes of 4:1 (four horizontal to one verticle) or flatter because a driver, forced onto such a slope, has a chance of regaining control of his vehicle. In some cases it is economical to flatten embankment slopes to 4:1 or less instead of constructing guardrail, provided right-of-way is available. For roads that must be

constructed on difficult terrain (mostly rolling to mountainous) depth of fill criteria should be followed. The park road designer must be sensitive to terrain conditions as the road type passes from access to circulation to the point of users destination in an activity area or facility. When considering fill slopes and drainage ditch design needs comparative cost studies of guardrail versus flatter side slopes should be made. See discussion in AASHTO, "A Policy on Geometric Design of Rural Highways", 1965. Savings in maintenance cost and for safety can be reasons for increasing the fill depth at which it is economical to flatten slopes rather than use guardrail. However, where there is an accident prone situation, even with flat slopes, there usually is reason for guardrails. With headwalls, interceptor drainage channels, trees, or other objects present on the flat slopes, the hazard is not greatly different from that on steep slopes.

(3) Other hazards to be protected by guardrail. While guardrails largely are used on fill sections, their need is recognized at abrupt changes in road cross section, at approaches to structures, or at drainage pickup points, even in cut sections to provide the essential delineation or warning. In such instances, delineators generally are more suitable, with guardrails being only infrequently required.

(4) Choice between guardrail or delineator. The choice of providing guardrails or delineators largely is a matter of the hazard involved. Guardrails are designed to resist impact by deflecting the vehicle so that it continues to move at reduced velocity along the guardrail. Any abrupt stop of a vehicle is dangerous and guidepost or projection on guardrails which might snag a moving vehicle is not desirable. The sudden stop may be more hazardous than the alternative. Delineators are especially desirable in areas subject to fog. Reflector surfaces or buttons on them greatly improve their visibility at night, when it is needed most.

(5) Delineators. Delineators should be designed so as not to resist impact. They are less costly than guardrail, but should not be used in lieu of guardrail where vehicles need structural restraint to prevent them from leaving the road. Locations frequently are encountered where many drivers are confused regarding the direction of the road, particularly at night. Delineators generally are used at such places. In general, horizontal curves can be outlined sufficiently by delineators on the outside of curve only. They should be continued for some distance on tangents at the ends of the curve.

(6) Location. Except at turnouts, guardrails and delineators should be located at a constant distance from the edge of pavement to avoid possible confusion in inclement weather as to their location. They should be located somewhat back from the usable pavement line and at about the same elevation. When guardrail is used it is desirable for a

short distance on the traffic approach end to sweep it outward and downward and tie it into the ground in order to lessen possible direct end impact and to provide a full view to the driver.

(7) Visibility. To be fully effective, guardrails and delineators should be highly visible and well maintained with reflector buttons or reflectorized material. Such highly visible treatments are good warnings for hazardous situations and add measurably to the comfort and ease of riding along the roadway. This factor alone may in many instances provide the reason for their provisions.

(8) Designs. Guardrail and delineators should be of designs customarily used by the state highway department, however, consideration should be given to the use of treated timber when wood meets the restraining needs. See Figure 2-8. When the roadway section requires more sure guardrail holding capacity, metal, concrete, or masonry wall types should be considered. Delineation and quasi guardrail devices, such as guideposts, boulders or other objects which would in themselves be hazards if struck by vehicles should not be used.

2-5. Intersection Design Elements.

a. General. An intersection is the point where two or more roads join or cross. Each segment of road radiating from an intersection is called leg. An intersection is an important part of a highway since much of the efficiency, safety, speed, cost of operation, and capacity is influenced by it. An intersection must handle through traffic as well as turning movements. Intersection design should give consideration to such features as alignment, sight distance, pavement width, grades, superelevation, and curbed channelization islands.

b. Sight Distance. The operator of a vehicle approaching an intersection should be provided unobstructed view of the entire intersection. All intersections for Corps recreation roads should be controlled intersections, i.e., STOP and YIELD signs should be provided at all intersections. Figure 2-2 shows design data for desirable sight conditions at the intersection of recreation and public roads.

c. Minimum Designs for Sharpest Turns (Fillet Radii).

(1) General. Where it is necessary to provide for turning vehicles within minimum space, as at unchannelized intersections, the minimum turning paths of the design vehicles apply. The paths of concern are the minimum attainable at low speed, less than 10 mph, which are a little above the minimum paths of nearly all vehicles in each class and, consequently, offer some leeway in driver behavior. Layouts patterned to fit these design vehicle paths are considered satisfactory as minimum designs. In the design of the edge of pavement for the minimum path of a

given design vehicle, it is assumed that the vehicle is properly positioned within the traffic lane at the beginning and end of the turn, i.e., 2 feet from the edge of pavement on the tangents approaching and leaving the intersection curve.

(2) Minimum radius for inner edge of pavement surface or fillet.

(a) Design vehicle P (passenger car). The minimum radius should be 30 feet.

(b) Design vehicle SU (Single unit truck or bus). The minimum radius should be 50 feet. In any design permitting the SU design vehicle to turn on its minimum path without swinging wide, the front overhang swings out 12 feet from the edge of tangent pavement on the far end of the turn, the vehicle fully occupying a 12-foot land on the crossroad. With 10- or 11-foot lanes, the vehicle would encroach on an adjacent lane. To preclude this, edge of pavement radii larger than the minimum indicated would have to be used.

(3) Additional minimum edge of pavement designs. It is emphasized that the radii prescribed herein are minimums and may be increased within a reasonable limit. For additional design information see AASHTO "A Policy on Geometric Design of Rural Highways", 1965. Table 2-12 gives minimum radii for intersection turns at various angles.

d. Speed Change Lanes. Speed change lanes would rarely be justified except where the access road to recreation land intersects a road or highway of a state, county or city system. They are not justified for an intersection with a public road or highway unless it is travelled by relatively large numbers of vehicles at relatively high speeds. For additional guidance refer to AASHTO, "A Policy on Design of Urban Highways and Arterial Streets, 1973.

e. Traffic Control Devices. All recreation road intersections should be provided with traffic control devices in accordance with the Manual on Uniform Traffic Control Devices for Streets and Highways, ANSI D6.1-1978. The minimum control should be erection of right-of-way assignment signs, either STOP or YIELD. Where needed STOP AHEAD or YIELD AHEAD signs should be erected. Cross Road Sign (W2-1, W2-2, W2-3), T Symbol Sign (W2-4) and Y Symbol Sign (W2-5) should also be used as appropriate on roads with design speeds in excess of 30 mph which are assigned the right-of-way at the intersection; i.e., STOP or YIELD signs installed on the other road leg or legs at the intersection. Intersections are about the most dangerous places on roads and deserve careful design efforts. Where traffic justifies, curbs and/or islands may be used to channelize traffic and they should be designed in accordance with local state highway department criteria or AASHTO policy. Also consult, ANSI 6.1-1978.

Table 2-12

MINIMUM EDGE OF PAVEMENT DESIGNS FOR TURNS AT INTERSECTIONS*

Design vehicle	Angle of turn	Simple curve radius
	degrees	feet
P	30	100
SU		100
P	45	100
SU		75
P	60	40
SU		60
P	75	35
SU		60
P	90	30
SU		50
P	105	**
SU		**
P	120	**
SU		**
P	135	**
SU		**
P	150	**
SU		**
P	180	**
SU	U-Turn	**

*Fillet radii
**Use minimum radii of 30' for vehicle P, and 50' for vehicle SU.

2-6. Drainage Structurces.

a. Hydraulic Design Frequency. Culverts should be designed to pass the runoff for hydraulic frequencies of 2 to 10 years. Minor bridges should be designed for hydraulic frequencies of 5 to 25 years. Major bridges (these will rarely be constructed in parks) should be designed for frequencies of 25 to 50 years. Selection of the design frequency should be influenced by consideration of the effects of traffic interruption, potential damage from runoff exceeding design runoff, and the importance of the road and structure size (See TM 5-820-4).

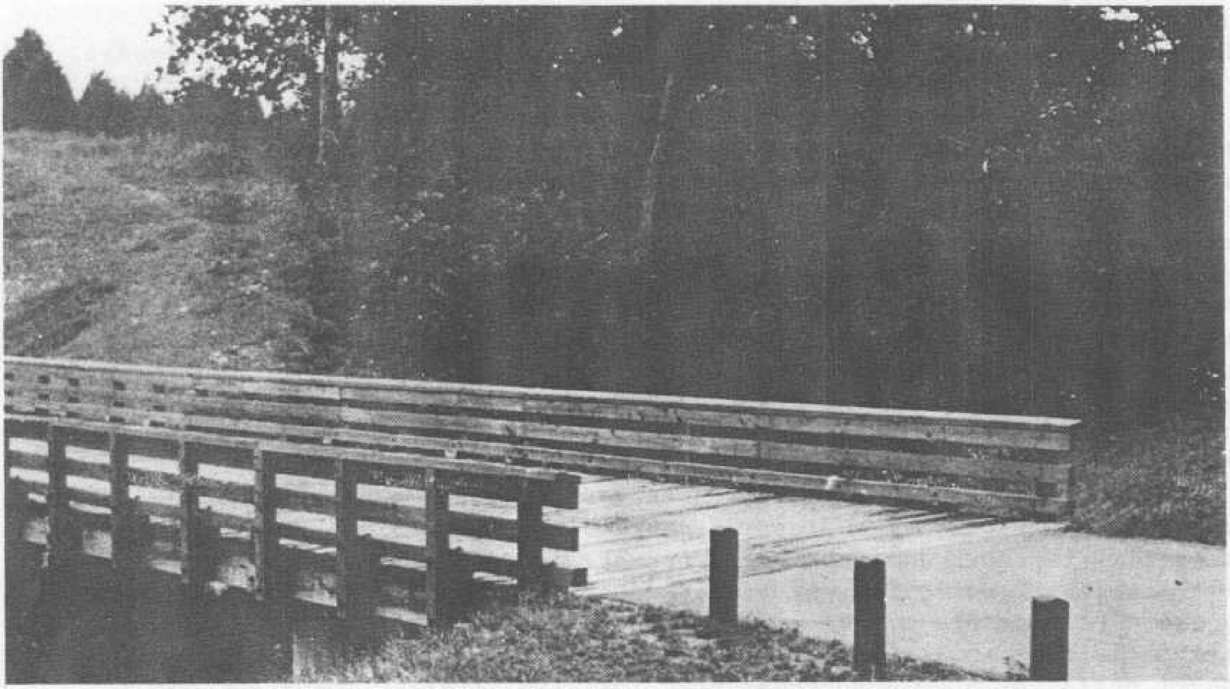
b. Culverts. Ditches should be relieved frequently to avoid carrying runoff for long distances in roadside ditches. In locating structures, the natural drainage pattern should be preserved as much as feasible. Contractor's option for use of reinforced concrete or corrugated metal for pipe culverts should be permitted where feasible. Careful attention should be given to proper setting of the outfall invert. Outfall protection and/or energy dissipaters should be provided where outfall velocities can be erossive (See TM 5-820-3).

c. Bridges. Bridges when required should be designed as economically as possible consistent with good architecture and protection of park aesthetics. H-15 loading will usually be adequate for recreation roads. Clear width of bridges should normally be equal to full roadway width including shoulders in accord with national policy on bridge safety. To provide access to isolated or low intensity use park areas, one-lane bridges may be provided in two-lane roads with appropriate warning signs. Bridges constructed of timber, masonry or native materials may be used. To save design effort for both reinforced box culverts and bridges, use of state standard designs is recommended. Furthermore, contractors tend to bid lower when standard state designs and specifications are used. Figure 2-10 is a typical bridge design for park area roads with low traffic volumes.

d. Improvised Structures. Nonstandard structures such as concrete slab ditch crossings, military field type expedient structures, log bridges, and other improvised structures may be used on minor circulation, service, and vehicular trail roads. Personnel should be alert for the possibility of using materials salvaged from the reservoir area.

e. Drop Structures. Liberal use of simply designed drop structures will help avoid deep and steep ditches (See TM 5-820-3).

f. Omission of Structures. On minor circulation roads and service roads, structures may be omitted with surface runoff conducted over the road by dips or sheet flow when soil conditions, paving materials, and terrain indicate that expensive maintenance problems would not be created by so doing. Dips may be paved or stabilized when needed. Low water crossings may also be advantageous in some instances.



2-7. Pavement Design Considerations.

a. Optional Designs. Use one of the following at the option of the District Engineer, advising in the appropriate D.M. which method was used:

(1) Follow the guidance in TM 5-822-2 to determine class of road based on anticipated design traffic used as average annual vehicles per day. Follow the guidance in TM 5-822-5 for design of flexible pavements using the design index for the anticipated traffic for design of surfaced access, circulation and service roads. For most roads a design index of two will be adequate. On a few roads, such as the main access road to a large park with extremely high visitation a design index of three or higher may be justified, but such roads will be rare. Where feasible, field CBR's (California Bearing Ratio) under existing pavements in similar soils should be considered in selecting the design value. Regardless of how the design CBR is selected, the object is to design for the actual field post-construction condition of the subgrade under the pavement. Usually flexible pavements will be less costly, but this depends on the economics of the project area. When rigid pavement is less costly or when it is to be used for short sections subject to frequent inundation it should be designed in accordance with TM 5-822-6.

(2) As an alternate to the above method, the state or local highway department design may be used. The design will be under secondary road criteria for roads with design traffic of 1000 vehicles per day and primary highway criteria for roads with design traffic over 1000 vehicles per day. It should be considered in designing under this method that highways are designed to support significant (not greater than 10%) numbers of commercial truck loads which may not be present on park roads.

b. Use of Local Materials. Maximum use of local materials and state specifications is encouraged. Specifications for base and sub-base materials should permit the contractor to exercise ingenuity in locating, producing, processing, and laying of base and sub-base courses. Specific requirements for bases and sub-bases such as abrasion and soundness may be waived where materials have demonstrated satisfactory performance in existing roads. Some examples of such materials are iron ore gravel, pit run gravels, caliche, sandshell and pit run quarry stone crushed on the roadway. When it is proposed to use such materials at a project, advance discussion with Division Engineer Office, Foundation and Materials Branch personnel is recommended.

c. Surface Course. Bituminous surface courses maybe placed as full-depth, directly on a prepared subgrade or on a 4-inch (minimum) base course. Bituminous surface treatments should not be placed directly on lime stabilized soils. Consideration should be given to use of asphaltic concrete when plants are located within economical haul distance and when life cycle cost indicates it is competitive with surface treatments. Gravel surfacing should be considered for light traffic roads and for all service roads.

d. Additive Stablization. Cement, lime, or bitumen - is recommended for roads and parking areas below the elevation of the 5-year frequency pool.

e. Upgrading of Local Materials. In designing pavements, full consideration should be given to upgrading locally available materials for base and sub-base courses with lime, cement, or bitumen.

f. Asphalt Emulsions. Designers should become familiar with and give consideration to the use of anionic and cationic asphalt emulsions in design of surface treatments.

g. Plastic Soil Binder. Materials used for open-surface, traffic bound pavements should contain sufficient plastic soil binder. Plasticity index (PI) range between 6 and 12 is preferred. Where suitable materials cannot be located or produced within economical haul distance which have PI within the preferred range, a range from 4 to 15 may be considered. Strength design is not required for open-surfaced roads. Such roads should be designed as all-weather easily maintained roads. The possibility of future surfacing should be considered in design.

h. Soil Stabilization. Stabilization should be designed following guidance in TM 5-822-4 or the design procedure of the state highway department of the state in which the road is located.

i. Pavement Design for Frost Conditions. The need for pavement design for frost conditions should be determine based on criteria in TM 5-818-2. If design for frost conditions is found to be necessary, pavement should be designed in accordance with TM 5-818-2. In making the determination of necessity consideration should be given to practices of the highway department of the state in which the project is located. In northern latitudes road paving costs can often be reduced by using free draining materials daylighted to drain. Roadside ditches in some cases can be cut deep enough to facilitate lateral drainage so that damaging freezing under the pavement surface will not occur.

j. Compaction. Compaction requirements should normally be based on modified density (AASHTO policy; ASTM, D 1557, or CE Modified Compaction Test, EM 1110-2-1906). The following minimum compaction requirements are suggested:

	Modified	Standard
Base Courses	100%	105
Sub-base Courses	95% to 100%	100-105
Top 6 inches Subgrade	90% to 95%	95-100
Fills	90%	95

k. Blanket Pavement Design. Blanket type pavement design sections will normally be used because of their superior performance. When trench design sections are used, the reasons should be given in feature design memorandums. Trench type sections generally should not be used in impervious soils.

2-8. Landscape Planting and Development.

a. General. Landscape development, to be effective, should begin with an analysis of the existing vegetation along the proposed route, looking for and directing the possibilities for conserving all desirable landscape features and scenic values. In order that the natural features of the route may be preserved, attention should be given during the preliminary design stage to the landscape existing and to that of the post construction. The ultimate recreation landscape development should be visualized in three dimensions; horizontal and vertical alignment and cross sectional elements. Each of these so coordinated as to produce a facility that will be attractive and be part of the recreation experience. All of the above elements of design when coordinated with landscape development should produce the best road in the best interest of the user and its cost of construction and maintenance.

b. Selective Thinning and Tree Protection.

(1) Trees to be preserved. Existing vegetation outside of the areas staked for clearing and grubbing should be appraised for preservation. Precaution should be taken for the protection of all desirable vegetation from damage during construction operations. Trees which do not interfere with sight distance nor create a hazard to roadway users and are on the edge of the construction limits should be given special protection during construction. Existing trees that provide shade, frame views, or have other values, should be saved on roadside borders where there is adequate clearance from the edges of pavements. For low speed circulation roads and loops inside activity areas, trees can be preserved right up to the pavement edge. The guidance given here amplifies that given in paragraph 2-4g, obstruction clearance. Figure 2-11 demonstrates landscape preservation and development inside activity areas. In some cases tree walls (to protect trees within cuts) and tree wells (to protect trees within fill sections) might be considered to preserve trees of outstanding character and value (Historical or cultural values). Specie tolerance to road conditions should also be evaluated.

(2) Trees to be removed. Existing vegetation (particularly trees) outside the limits of clearing which are determined to be in poor or unsatisfactory condition horticulturally, should be removed. Every effort should be made to save diseased or partially deteriorated trees and other vegetation by applying the best horticultural practices.

c. Planting Design. Landscape planting for recreation roads should serve specific purposes. Because trees and shrubs create a third dimensional effect in the recreation road cross section special design considerations are needed. Before planting plans are prepared each recreation road should be analyzed to determine (1) the purposes for which planting may be needed; and (2) the controls governing the feasibility of planting and influencing the planting design.

(1) Planting purposes. Planting of recreation roadsides should be designed to serve one or more of the following purposes:

(a) Protecting slopes from erosion.

(b) Screening traffic from recreation areas and facilities including accaustical control.

(c) Providing advance warning to traffic along road way approaches to structures.

(d) Guiding traffic by indicating need for turning movements.

(e) Reduce maintenance through elimination of mowing.

(f) Increase aesthetic values by framing desirable views and roadway structures, blending new construction areas into the natural surroundings, and providing variety and interest of the roadside especially between areas of cut and fill.

(g) Enhance the recreation facilities.

(h) Delineate roadway alignment where delineation by natural conditions do not exist.

(i) Provide shade at scenic overlooks.

(j) Supplement existing vegetation at the tree edge to improve the appearance of the areas.

(k) Glare and reflection control.

(l) Modification of climate.

(m) Wildlife habitat.

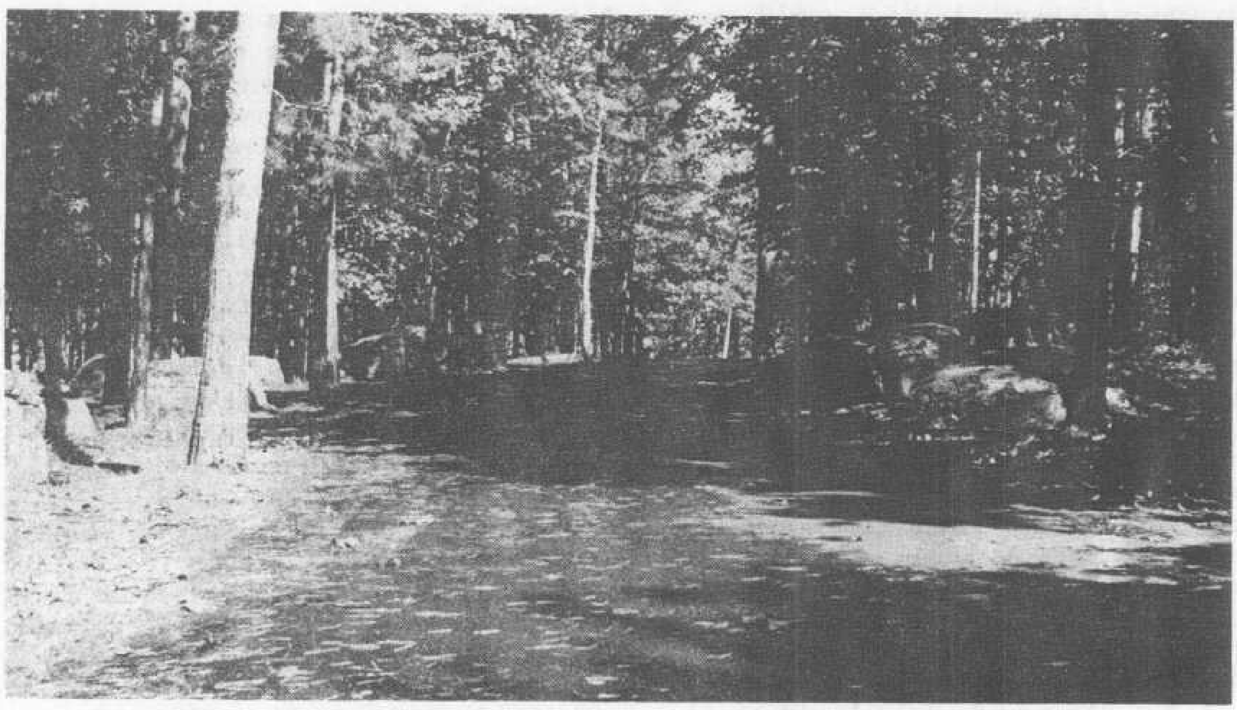


Figure 2-11 Preservation of Landscape Features

(2) Planting controls. Limitations of the existing surroundings, planting clearances, scale, and future maintenance should be considered in the design of planting.

(a) Existing surroundings. Appropriate planting should be designed to tie the recreation road into its environment in keeping with (1) the character of the surrounding terrain and existing vegetation, and (2) the planned recreation use. Existing trees and other natural growth conserved during construction should be supplemented as necessary. New plantings may be justified in open areas, on cut and fill slopes and in recreation use areas. Such planting should be naturalistic and similar to existing growth. Trees and shrubs should usually be arranged in natural groupings in keeping with the recreation setting and the open countryside.

(c) Planting clearances. Horizontal clearances for recreation roadsides is given in paragraph 2-4g (1) however, certain design philosophy regarding specific relationships of recreation roads, planting clearances and user facilities enhancement should be considered in the design of roadside plantings. Since shade is one of the amenities recreationists seek in the outdoors, trees and shrubs along roadways should be planted to meet the requirement of safety of the motorist and park user and enhance the facilities being used and the roadway scenic values. Trees and shrubs should not be planted close to drainage structures where blockage could occur. All plantings of trees and shrubs along recreation roads should take into consideration ultimate spread of plants so that when fully grown, there will be no interference with signs, overhead clearance, and integrity of roadway safety. Some allowance can be made for maintenance which is necessary along most roadways.

(d) Types and scale. Generally the types of plant materials which are effective in recreation road planting are: (1) high-headed medium-growing trees (deciduous and evergreen), (2) small flowering trees, and (3) medium and small shrubs, vines or turf grasses. Of this group, small flowering trees may be the most important group of plant material for use in the recreation area. There is a plus if they have outstanding fall foliage and visible fruit. Small flowering trees can be used to tie the scale of the road to the scale of the recreation area better than any other plant type. Shrub type materials are best used only in mass plantings. Low-growing shrubs may be desirable at selected points to reduce mowing and to relate the road to wooded areas. The scale of planting should be related to the road, structures, and the recreation area and facilities. Species of trees and shrubs native to the local area should be used if possible. Wildlife values to be obtained should be considered in addition to aesthetics and other values. Plant material should be in accordance with the American Nursery Growers Standards and should be inspected by a qualified expert prior to planting.

(e) Maintenance. During the process of selection, arrangement, and application of plants, the designer should give consideration to maintenance capabilities of the park manager. Reduction of mowing should be an objective of the roadside planting design. Slopes where possible should be planted with ground cover and permitted to acquire natural vegetation. Plant-bed outlines adjacent to planned turf areas should be designed with low sweeping lines to permit ease of mowing. Except to the extent required for safety, slopes should not be mowed, not only for economy, but also mowing prevents natural development of indigenous woody plant growth. Degree of mowing should also be considered (three mowings per recreation season might suffice). This type of information should be set out in the design process.

2-9. Miscellaneous Considerations.

a. Clearing and Grubbing. These items should be held to the minimum feasible. Plans and specifications should clearly define the limits of clearing and grubbing. The limits should be marked in the field by the Government or the contractor prior to beginning clearing operations. The plans and specifications should indicate who will do the marking. If the limits are marked by the contractor, they should be approved by the contracting officer before beginning clearing operations. Any necessary haul roads or contractor work areas should be similarly handled. Haul roads should traverse permanent road alignments and already cleared areas as much as feasible. Haul roads should be laid out along curving alignments so that the scar they cause will be less apparent than if straight lines are used. The plans and specifications should require the contractor to operate his equipment within the limits of clearing. Reasonable provisions should be included in the technical provisions to discourage the contractor from damaging vegetation or land forms outside the authorized limits of clearing. Clearing for roads should not extend beyond the toe of fills or the top of backslopes in cuts. Where necessary to save particularly desirable tree or group of trees, the lanes of two-lane roads may be split apart, leaving a median between to contain the trees. Grubbing should not be permitted beyond the bottom of the ditch in cuts or beyond the edge of subgrade preparation in fills. Selective clearing and underbrushing may be omitted from construction contracts because it is costly to perform and difficult to get done satisfactorily by contract because overclearing usually results. Refinements in clearing often can best be accomplished later by Government personnel such as summer hires.

b. Top Soil Stripping. Stripping should be just deep enough to assure that the amount of roots and other organic material not removed will be too small to cause construction of a poor subgrade. This amount of stripping can usually be obtained with light blading with a motor patrol and windrowing laterally to the limits of clearing. After grading is completed, the windrowed material, if suitable, may be pulled back and spread on the slopes.

c. Borrow Areas. These should be subject to the approval of the contracting officer. They should be located in areas where they are concealed from view or blended in with the natural surroundings. Borrow areas located within the park should be located as remote as economically feasible from developed areas or future developed areas and preferably out of view of most of the visitors. The location of borrow areas should be shown on the plans to permit bidders to estimate haul cost. Borrow areas should be graded at the end of operations to drain and blend naturally with establish vegetation. Borrow areas should be within the conservation pool when possible.

d. Finishing Rock Cuts and Fills. Finish of rock cuts should be controlled by specifying tolerance, instead of requiring 6 to 8 inches of undercutting below subgrade and backfilling with a suitable material. Specifications should require contractors to save sufficient suitable material for topping out and finishing rock fills. Erosion resistant rock slopes should not be flattened merely to provide areas flat enough to grow turf. Steep bare cut banks can present interesting geological exposures which may enhance the landscape by providing contrast between the paved road surface, turfed foreslopes and the greenery beyond the backslopes.

e. Payment for Grading. The discussion given here on payment for grading is directed toward providing information on a possible alternative for payment of grading work for park roads. There is an advantage to paying for road grading by the station. Roads that must be constructed in moderately rolling to flat terrain, grading work could be accomplished by motor grader instead of heavier equipment. This type of grading is especially needed inside the activity area, i.e., near the picnic area and camping loop roads. When payment is by the station, the incentive to the contractor is to do as little grading as he can. When payment is by the cubic yard, experience has shown in some localities, the incentive to the contractor is to do as much grading as he can. There is a disadvantage to payment by the station in that bidders cannot determine the amount of work as closely as they can when payment is by the cubic yard. However, it is considered that a little higher cost is justified to preclude over-grading and to obtain park-like roads. When payment is by the cubic yard, quantities and earthwork balance points should be shown on the plan-profile sheets. Payment by the cubic yard should be used for heavy grading (moderately rolling to mountainous terrain) in fairness to both the bidder and the Government; however, heavy grading should be avoided as much as possible in parks.

f. Maintenance and Restoration. As standard materials run short, there will be an increasing emphasis on the development of more economical maintenance and restoration techniques. Unfortunately, the variability of climates and geology makes generalization concerning the cost effectiveness of such techniques quite indefensible. Maintenance techniques must be evaluated on a site and project specific basis.

g. Planning and Design Techniques. Increased costs and environmental concerns require roadway planners and engineers to investigate and more thoroughly evaluate the consequences of road location decisions. Three techniques, primarily using a combination of computers and revised field design techniques, are discussed here.

(1) Topometrics. A technique using topometrics has been developed to assist the planner or engineer in efficient evaluation of alternative routes. Topometrics is the process whereby numeric information is obtained from topographic maps by measuring three-dimensional differences of coordinates. The topometric process translates graphic position into a format that lends itself to numeric methods of analysis.

(a) The system which uses desk top computers with digitizers, plotters, printers and specially designed software routines offers a low cost, readily available route evaluation system. The system allows the user to evaluate routes based on horizontal alignment, earthwork and mass diagram computations. The technique allows the user to participate in an interactive process that allows him to see the results of basic decisions, make desired changes and carry out many more design cycles than are possible with manual methods. Alternative route evaluation can be conducted at a rapid rate, up to 1,000 feet per minute, depending on map scale. The system provides a quantitative output enabling the user to easily evaluate cost, safety and aesthetic factors.

(b) In addition to evaluating such factors as cost and safety, the planner or engineer may address other more subtle considerations. Route aesthetics are a function of the total amounts of material moved, depths of cut and fill, exposure of cut and fill slopes, road suitability, and proximity to sensitive areas such as recreation sites, viewing points and scenic overlooks. Unacceptable routes can be identified and eliminated and the most economic and environmentally promising routes can be scheduled for field verification.

(2) Computer aide design system. The U.S. Forest Service utilizes a computer-aided design system called the Forest Service Road System (FSRDS). The FSRDS is a comprehensive set of interrelated computer programs for processing road designs from the initial traverse to construction earth work quantities. Though somewhat complex and developed primarily for design of lengthly low-class road systems, portions of the FSRDS have possible applicability to design of Corps recreation area roads.

(a) The FSRDS is a "computer-aided" system in which the user is relieved of the repetitive computational tasks associated with roadway design. The user is allowed the luxury of considering more imaginative concepts and thus generate better designs.

The complete FSRDS system contains over 30 interrelated design programs and provides the user with data on which to make a decision as to his next course of action.

(b) Although FSRDS will handle the design of any individual type of road, it was primarily developed for the evaluation of low volume roads. There are several individual programs within the system that allow efficient design of low volume roads. The design modules require minimum inputs of profile grade, slope selection information, template information and earthwork compaction factors. The computed output for each roadway station includes: (1) grade elevations; (2) average side slope; (3) topography limits, the distance left and right of baseline centerline that the design template can be moved; (4) limits of cut and fill, how far the template can be shifted left and right of base-line centerline based on maximum cut and fill height; (5) daylight offset; (6) self balanced offset; and (7) approximate station by station quantities.

(c) The Forest Service has used FSRDS for more than 15 years and has great confidence in the system's efficiency and effectiveness as a tool for helping the roadway designer and the on-the-ground land manager make decisions concerning road design and construction. The Forest Service has found that the system allows the user to fit the road to the ground with minimum impact and still consider cost, safety and aesthetics factors.

(3) Field design. The Forest Service has also investigated techniques involving field design of forest roads. Although the technique is primarily suitable for the design of low standard roads, the concepts may have application to Corps recreation road planning, design and construction, particularly local, sublocal and service roadways.

(a) Prior to development of the field design methodology, the Forest Service used the conventional P-line, L-line survey-design methodology. This conventional method of roadway design involves the establishment of roadway slope stakes through the use of a preliminary survey of the road line (called a P-line survey), an office design from the P-line data, and an additional survey of the designed roadline (called a location or L-line survey) to establish a line from which to stake the roadway slope. The road is then slope staked and referenced prior to construction. The field design methodology essentially eliminates the initial P-line survey, or actually consolidates the P-line survey office design and L-line into one continuous process.

(b) Development of the field design methodology has been evolutionary rather than revolutionary. For design of low class roads, the Forest Service reports substantial savings in manpower and design efforts. In one case, survey and design of a 3.5 mile low type road was accomplished in 12 days. Conventional P-line methods were estimated to require 3 months. The field design methodology is generally estimated to require from 10 to 15 percent of the effort required for conventional design.

(c) The field design methodology has not only resulted in manpower savings but has produced aesthetically pleasing roadways with minimal impact on the land. Greater environmental impact has been found when conventional office design techniques are utilized. In test cases, field designed roads were found to be indistinguishable from those that are conventionally designed.